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OHMSETT (Oil and Hazardous Materials Simulated Environmental Test Tank) Skimmer Test in Ice-Infested Waters

Mason and Hanger-Silas Mason Co., Inc.
Leonardo, NJ

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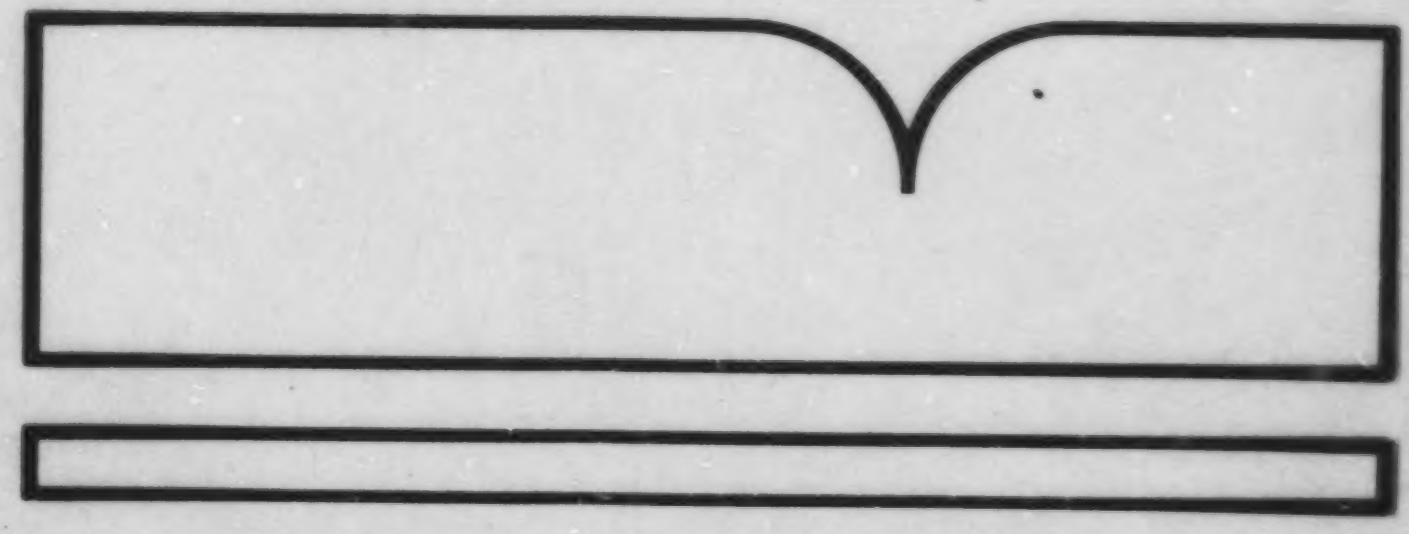

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by

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16. ABSTRACT

The increase in petroleum development activities in the arctic region has raised concerns over potential oil spills during the broken ice season. Currently, exploratory drilling for oil and gas is restricted during this season due to the lack of oil spill cleanup methods that have been proven effective in broken ice fields. Test programs have been conducted at the United States (U.S.) Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) to determine the feasibility of cold-weather testing; and to evaluate various oil spill cleanup methods that are being considered for use in the arctic. This paper describes a test program conducted to determine the practicality of using a catamaran-mounted rope mop skimmer for spill cleanup in broken ice fields.

The skimmer was tested in the test tank under controlled conditions during January 30 to February 7, 1984. Fresh-water ice cubes of 250 to 280 millimeters (mm) were used in the tests to approximate a broken ice field. During tests, a predetermined ice condition was established across the encounter width of the rope mops, and oil was distributed over the ice. The oil and ice were channeled into the skimmer by two booms, which were joined to the skimmer at the bow.

Nine tests were conducted at a tow speed of 1 knot using Circo 4X light oil. During the tests, ice concentrations were varied from 0 to 75 percent of the surface area, and oil slick thicknesses were varied from 3 to 8 mm. The test results demonstrated the spill cleanup capability of the skimmer in ice-infested waters having up to 50 percent ice coverage. At higher ice concentrations, the skimmer was ineffective due to ice jamming at the skimmer inlet.

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ABSTRACT

The increase in petroleum development activities in the arctic region has raised concerns over potential oil spills during the broken ice season. Currently, exploratory drilling for oil and gas is restricted during this season due to the lack of oil spill cleanup methods that have been proven effective in broken ice fields. Test programs have been conducted at the United States (U.S.) Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) to determine the feasibility of cold-weather testing; and to evaluate various oil spill cleanup methods that are being considered for use in the arctic. This paper describes a test program conducted to determine the practicality of using a catamaran-mounted rope mop skimmer for spill cleanup in broken ice fields.

An Oil Mop Pollution Control, Ltd. prototype arctic skimmer was tested in the test tank under controlled conditions during January 30 to February 7, 1984. Fresh-water ice cubes of 250 to 280 millimeters (mm) were used in the tests to approximate

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Nine tests were conducted at a tow speed of 1 knot using Circo 4X light oil. During the tests, ice concentrations were varied from 0 to 75 percent of the surface area, and oil slick thicknesses were varied from 3 to 8 mm. The test results demonstrated the spill cleanup capability of the skimmer in ice-infested waters having up to 50 percent ice coverage. At higher ice concentrations, the skimmer was ineffective due to ice jamming at the skimmer inlet.

INTRODUCTION

This paper presents the results of a test of an oil skimmer in ice-infested waters at the United States (U.S.) Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT). The test was one of two test programs on the evaluation of oil spill cleanup capabilities in broken ice sponsored by the OHMSETT Interagency Technical Committee (OITC) during 1984. The committee consists of representatives from the Minerals Management Service, U.S. Coast Guard, U.S. Environmental Protection Agency, Canadian Environmental Protection Service, and the U.S. Navy. The continued expansion of petroleum exploration at the arctic and the lack of documented cleanup capabilities for potential spills from these activities in broken ice have created the need to conduct tests under controlled conditions at OHMSETT's environmentally safe test tank. The test programs were conducted to demonstrate the feasibility of cold-weather testing at OHMSETT. Known cleanup methods considered to have potential applicability in broken ice were selected for the tests. The test program on mechanical spill cleanup with a rope mop skimmer is described in this paper (Shum, 1984).

The skimmer was tested in broken ice in OHMSETT's test tank from January 30 to February 7, 1984. Nine test runs were made at ambient temperatures of -3 to 9° Celsius (C). During the tests, fresh-water ice cubes 250 to 280 millimeters (mm) were used to approximate the broken ice conditions. Tests were conducted with ice concentrations ranging from 0 to 75 percent using Circo 4X light oil. The originally planned test oil, Prudhoe Bay crude, did not arrive on time for the test. The Circo 4X light oil from OHMSETT's inventory was selected because its low viscosity closely approximating that of the Prudhoe Bay crude oil. Table 1 is a summary of the physical properties of the test oil.

SKIMMER DESCRIPTION

A rope mop skimmer designed for use in the arctic was made available for testing at OHMSETT by the Canadian Environmental Protection Service. The arctic skimmer was a prototype developed and fabricated by Oil Mop Pollution Control, Ltd., Mississauga, Ontario. The skimmer consisted of three oleophilic rope mops mounted between the hulls of an aluminum catamaran, 4.6-meter (m) long and 2.4-m wide. The channel between the two hulls diverged from 813 mm at the bow to 876 mm at the stern to ensure a free passage of ice through the skimmer. The three rope mops were each 304 mm in diameter and approximately 9.6-m long, mounted in a loop along the length of the catamaran. At the water surface, the mops travelled from the bow to the stern, where they were pulled up from the water surface. All three mops were driven and squeezed by a wringer assembly located at the bow. The wringer speed was adjustable to enable the skimmer to operate in a zero relative velocity (ZRV) mode.

The skimmer was equipped with a rotary-type positive-displacement pump to off-load recovered oil. A single diesel engine-driven hydraulic pump powered the wringer, the oil discharge pump, and other accessories, which included two outboard motors with steering controls and an oil-herding water pump. After starting the engine, the skimmer operations were remotely controlled from a radio control unit.

TEST SETUP

Figure 1 is a photograph of the skimmer in the 203-meter-long, 20-meter-wide, above-ground, concrete test tank. The skimmer was positioned close to the west tank wall (approximately 1.8 m to the center line of the skimmer) in order to facilitate ice distribution from the side of the tank. During testing, the skimmer was towed by OHMSETT's main bridge along the length of the tank from north to south. Two 7.3-meter-long boom sections were installed from the bow of the skimmer to the main bridge. The booms served to channel the ice and the test oil into the space between the catamaran hulls. The boom openings were 2.5 m apart at the main bridge and 813 mm at the skimmer bow.

The various ice coverage conditions for the test were established only for the water surface encountered by the oil recovery elements, the rope mops. The percent ice coverage, therefore, referred to a water surface bound by the test tow length and the opening between the hulls of the vessel, i.e.:

$$C = 3.24 \frac{I}{V \times T \times D} \qquad \text{Equation (Eq.) 1}$$

where

- C is the ice coverage condition for the test, percent
- I is the total surface area covered by ice, m^2
- V is the tow speed, knots
- T is the test time interval, minutes (min)
- D is the skimmer inlet width (distance between the hulls), m
- 3.24 is the unit conversion factor

The required quantities of ice for each test were manually preloaded into the tank. The ice blocks were prevented from drifting by a set of ropes (one at the water

surface and one 150-mm below). These ropes were positioned approximately 2.2 m from the tank wall and stretched lengthwise between the main bridge and the south end of the tank. As the main bridge advanced to the south during testing, the rope tensions were maintained by continuously retracting the ropes onto the rope reels that were on the main bridge.

The test ice was cut from commercially available ice cakes with nominal dimensions of 1220 mm x 610 mm x 305 mm. Each ice cake was cut with an ice pick into eight equal pieces (as determined visually). Due to shrinkage and fragmentation, the actual ice cube sizes after cutting typically varied from 250 mm to 280 mm.

A 61-meter-long platform was built along the edge of the test tank. The number of ice cubes required to establish the test ice coverage condition were distributed over the entire test length on this platform prior to preloading into the tank. The ice distribution was determined by

$$N = 0.01 \frac{D \times C}{A} \qquad \text{Eq. 2}$$

where

N is the number of ice cubes per unit tank length, m^{-1}

D is the skimmer inlet width (distance between the hulls), m

C is the ice coverage condition for the test, percent

A is the surface area coverage per ice cube, m^2

Special markings were placed on the ice platform at convenient equal intervals so that the required test conditions could be setup with an integral number of ice cubes between these markings. To facilitate the test setup, a constant value of A based on the surface area covered by a 305-mm ice cube was used in Eq. 2. Table 2 shows the test ice distribution on the platform for the various test conditions. For each test, the ice cubes were distributed over a length of about 55 m.

TEST PROCEDURE

On the morning of a test day, any naturally formed ice in the test tank from a cold night was cleared from the test area. This was achieved through one or more of the several established winter tank operating procedures for breaking and pushing the ice.

Prior to the start of each test run, the wringer was started and the mops' speed adjusted to the test tow speed (to achieve a zero relative velocity effect). The oil discharge pump, which was controlled by the same wringer on-off switch, was activated at the same time the wringer was started. Both the wringer and the oil discharge pump were left running while the ice blocks were preloaded (manually dropped) into the test tank between the restraining ropes and the tank wall.

The tests started after all the ice blocks had been thrown into the water. The main bridge started at a position about 15 m north of the ice platform to allow sufficient time for the skimmer to reach the test tow speed prior to encountering the ice. As the main bridge passed over the ice, oil was distributed onto the ice-water surface. The oil slick and the ice blocks were then guided into the skimmer opening by the booms. The rate of oil distribution was determined by the test oil slick thickness, tow speed and ice concentration:

$$Q = 0.0185\, D \times V \times S \times (100-C) \qquad \text{Eq. 3}$$

where

- Q is the oil distribution rate, cubic meter/hour (m^3/h)
- D is the skimmer inlet width, m
- V is the tow speed, knots
- S is the average test oil slick thickness between ice, mm
- C is the test ice coverage condition, percent
- 0.0185 is the unit conversion factor

During the test, the oil distribution rate was monitored by a flow meter with an analog indication and flow totalizer. At the end of the oil distribution, the total volume and the duration of oil distribution were recorded.

The recovered fluid during the first 30 seconds (sec) after the skimmer encountered the oil slick and/or ice was collected in a slop tank. At a speed of 1 knot, the mops completed about 1½ revolutions during this time. The skimmer was then presumed to be in a steady-state operating condition for the test. The recovered fluid during the steady-state condition was collected for 1 minute (min) in a separate collection tank. At the end of the 1-minute period, the skimmer was near the end of the test tow, and recovered fluid was again directed into the slop tank.

At the end of each test, the height of the total recovered fluid in the collection tank was measured and converted into volume. Free water was then drained. After the remaining fluid height was measured (for volume determination), a composite sample was taken for analysis of water and bottom solids.

After each test, the test area was cleared of the unrecovered oil and the contaminated ice blocks to prepare for the next test. The contaminated ice blocks were pushed to the north end of the test tank and were left there until they all melted. The remaining oil was skimmed off and hauled away by a waste oil disposal firm.

TEST RESULTS

The test conditions and the steady-state results for the nine tests are shown in Table 3. All of the tests were conducted with the same test oil, Circo 4X light, at a tow speed of 1 knot in calm water (no wave). The independent test variables were nominal ice coverage and oil slick thickness. The nominal ice coverage for each test was established by Eq. 2 and set up as shown in Table 2. The oil slick thickness was the calculated average slick thickness between ice during the test using Eq. 3. The oil distribution rate shown in Table 3 was computed from the recorded total volume and the duration of oil distribution during the test. The performance of the skimmer was evaluated in terms of the following parameters:

Oil Recovery Rate (ORR) - The volume of oil recovered per unit time.

Recovery Efficiency (RE) - Percentage of oil in the recovered fluid.

Throughput Efficiency (TE) - The ratio of oil recovery rate to oil distribution rate, in percent.

Tests No. 1, 2, 3, 4 and 7 were conducted with ice coverage varied from 0 to 75 percent. Tests No. 1 and 2 were repeated to verify the earlier results. Of the two tests at 50 percent ice coverage, one test (Test No. 2R) showed ice jamming at the skimmer inlet. During Test No. 4 with 75 percent ice coverage, the skimmer inlet was completely jammed with ice. The ice blockage at the skimmer inlet also prevented the oil slick from entering the skimmer. The recovered fluid contained only traces of oil and could not be sampled for analyses. During both of these tests, an operator was positioned at the bow to free jammed ice with a boathook. This operation was, however, ineffective in alleviating the jamming problem.

Tests No. 5 and 6 examined the effect of oil slick thickness. Test No. 6 was intended to be run at an intermediate oil slick thickness between 3 mm and 8 mm. At the end of the test, it was found that oil quantity corresponding to an 8-mm slick was distributed during the test.

CONCLUSIONS AND DISCUSSION

From the test results, the following conclusions can be made.

1. The rope mop skimmer was able to pick up oil in broken ice with ice concentrations less than 50 percent. In tests where ice concentrations exceeded 50 percent, ice jammed at the skimmer inlet and prevented the oil slick from entering the skimmer.
2. The ORR varied inversely with ice concentration within the effective range (i.e., with less than 50 percent ice concentration) of the skimmer. This could be attributed to the fact that, for equal oil slick thickness

between the ice blocks, the quantity of oil available for recovery was less with increased ice concentration. In addition, an increase in ice concentration resulted in a reduction of the contact surface area between the mops and the oil slick. No well defined relationship was observed for the RE and the TE as ice concentration varied.

3. The effects of slick thickness on skimmer performance in broken ice were similar to those observed in previous OHMSETT tests of ZRV skimmers without ice (Breslin, 1978 and 1980). Both the ORR and the RE increased with an increase in slick thickness. The TE was lower at the higher slick thickness.

The limited number of test runs did not offer a complete explanation of the observed data, which was the result of a complex interaction among the rope mops, ice, and oil, as well as the physical nature of the mop material, and the mechanical design and operation of the skimmer. As the ice blocks entered the skimmer, they were observed to stay either between the mops or under the mops. This random mop-ice interaction resulted in a varying degree of mop-to-oil slick contact. Where mops were on top of the ice blocks, light (unsaturated) spots on the mops were visible as they were pulled up from the water. The effects of tow speed and ice size were not examined in this program.

The skimmer's oil recovery effectiveness with less than 50 percent ice cover was found to be comparable to other rope mop skimmers tested in ice-free waters. Typical rope mop skimmer performance ranges in calm, ice-free waters, and in calm, ice-infested waters are shown in Figures 2 and 3. The data were based on the results from this test program and earlier tests of other catamaran-mounted rope mop skimmers at OHMSETT (Breslin, 1978, Lichte et al, 1981; and Urban et al, 1978). The skimmers tested were all of different designs, sizes and were tested under different conditions. Specific skimmer data and the test conditions are shown in Table 4.

The test program demonstrated the feasibility of conducting cold-weather testing with ice in OHMSETT's test tank. Control of test conditions was complicated by the addition of ice into the test medium, particularly under high ice and/or low oil conditions. Due to the large quantities of ice involved in the tests, accurate controls on the uniformity of ice size and ice distribution were compromised for additional test runs. The presence of ice restricted spreading of the oil slick to uniform thickness. For tests under low oil distribution conditions, the rope mops probably were not completely precharged with the oil prior to the starting of the steady-state fluid recovery. The inherent random nature of mop-ice interaction added yet another variability to skimmer performance.

REFERENCES

1. Breslin, M. K., 1978. Performance Testing of Oil Mop Zero Relative Velocity Oil Skimmer, EPA-600/7-78-060, U.S. Environmental Protection Agency, Cincinnati, OH.

2. Breslin, M. K., 1980. Performance Tests of High Speed ZRV Oil Skimmer, U.S. Coast Guard, Washington, D.C.

3. Lichte, H. W., M. K. Breslin, G. F. Smith, D. J. Graham and R. W. Urban, 1981. Performance Testing of Four Skimming Systems, EPA-600/2-81-189, U.S. Environmental Protection Agency, Cincinnati, OH.

4. Shum, J. S., 1984. Test of a Skimmer in Ice-Infested Waters at OHMSETT, Project Report (in preparation), U.S. Environmental Protection Agency, Cincinnati, OH.

5. Urban, R. W. and D. J. Graham, 1978. Performance Tests of Four Selected Oil Spill Skimmers, EPA-600/2-78-204, U.S. Environmental Protection Agency, Cincinnati, OH.

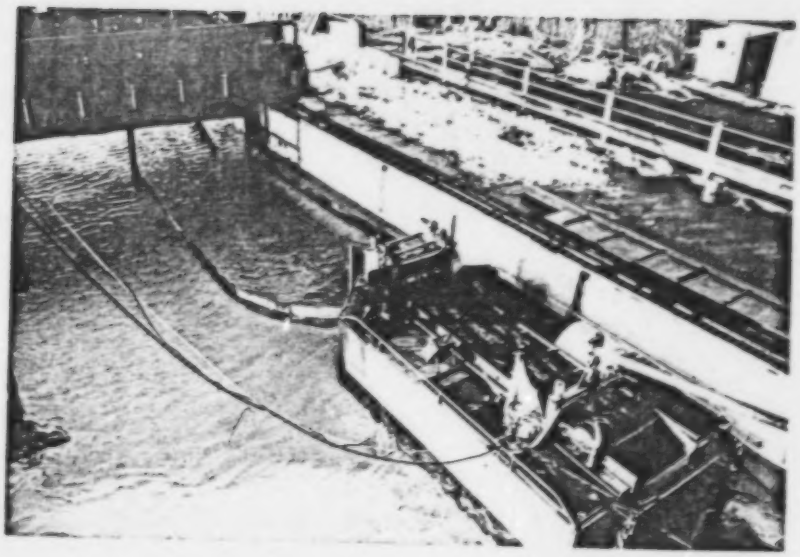

Figure 1. Photograph of the test setup. During test, the skimmer was towed from north to south. The ice distribution platform along the west tank wall is shown to the right of the skimmer.

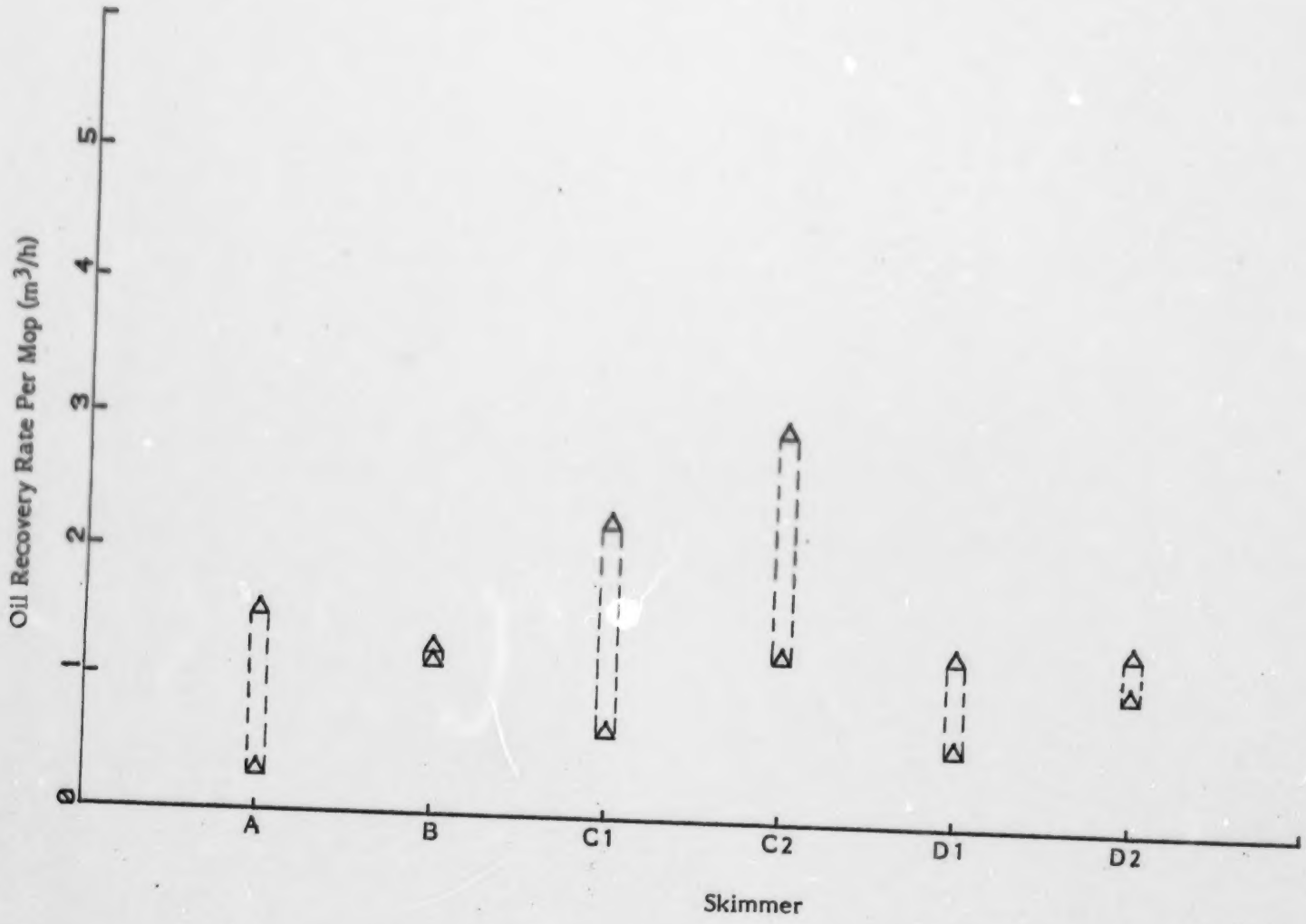

Figure 2. Oil recovery rates of typical rope mops (see Table 4 for descriptions of the skimmers and the test conditions).

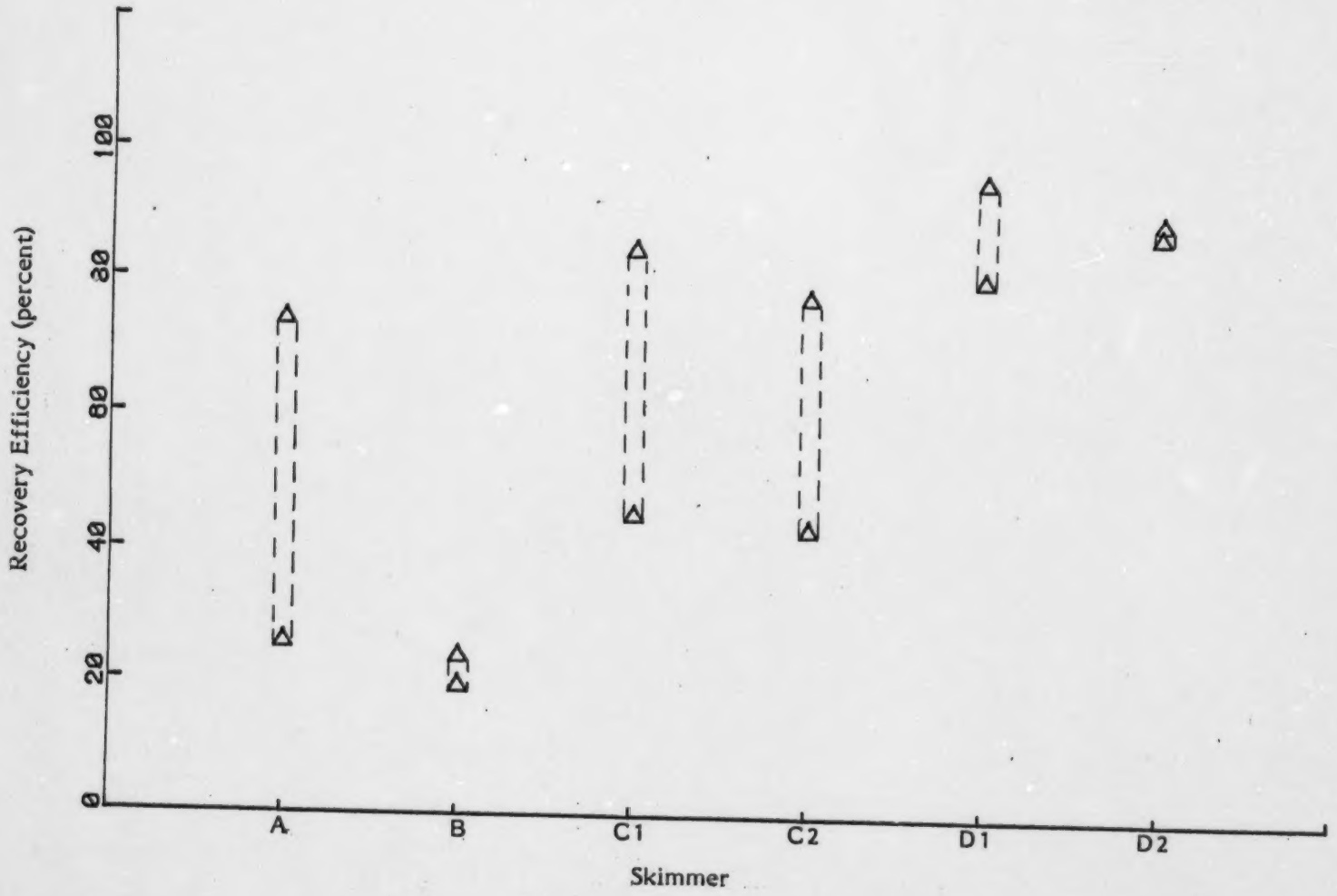

Figure 3. Recovery efficiencies of typical rope mops (see Table 4 for descriptions of the skimmers and the test conditions).

TABLE 1. TEST OIL PHYSICAL PROPERTIES

Oil Type	Circo 4X Light
Viscosity (centistokes)	16.6 @ 21.5°C 11.2 @ 36.1°C
Specific Gravity	0.903 @ 21°C 0.891 @ 36°C
SFT (dynes/centimeter)	30
IFT (dynes/centimeter)	6
% Bottom Solids & Water	< 0.02

SFT - Surface Tension

IFT - Interfacial Tension

TABLE 2. ICE DISTRIBUTION FOR VARIOUS TEST CONDITIONS

Nominal Ice Coverage (%)	Ice Cubes per Unit Tank Length (m^{-1})	Number of Ice Cubes at 0.6 m Interval	Number of Ice Cubes at 1.8 m Interval
25	2.2	N/A	4
38	3.3	2	N/A
50	4.4	N/A	8
75	6.6	4	N/A

N/A - Not applicable

TABLE 3. TEST RESULTS

Test No.	Test Date	Water/Air Temperature (°C)	Nominal Ice Cover (%)	Oil Slick Thickness (mm)	Oil Distribution Rate (m^3/h)	Tow/Mop Speed (knots)	ORR (m^3/h)	RE (%)	TE (%)
1	02/02/84	-0.6/-(a)	25	3	3.52	1/1.00	1.84	36	52
2	02/02/84	1.1/0.0	50	3	2.25	1/-(b)	1.68	59	75
3	02/03/84	1.1/5.0	0	4	5.54	1/0.91	2.88	50	52
1R	02/03/84	1.7/7.5	25	3	3.41	1/0.97	2.85	57	83
4(c)	02/03/84	2.8/9.4	75	3	1.18	1/0.94	0.09(d)	2(d)	8(d)
5	02/03/84	2.8/8.3	25	8	8.77	1/1.00	4.59	62	52
2R(c)	02/07/84	0.6/-3.3	50	3	2.34	1/1.07	0.95	74	41
6	02/07/84	0.6/-1.1	25	8	8.56	1/1.19	3.84	70	45
7	02/07/84	1.1/-1.9	38	3	2.95	1/0.70	0.95	26	32

Notes:
(a) Not recorded.
(b) Mop speed was presumed to remain the same as in Test No. 1 and was not checked during test.
(c) Ice blockage at skimmer inlet occurred during the test.
(d) Results are visual estimates. Sample could not be obtained for analysis.

TABLE 4. TEST CONDITIONS FOR DATA SHOWN IN FIGURES 2 AND 3

Skimmer	Type	No. of Mops	Mop Size	Type of Water Body	Tow Speed (knots)	Oil Type	Slick Thickness (mm)
A[a]	Arctic Rope Mop Skimmer	3	304 mm dia. 9.6 m length	0-50% broken ice cover - calm	1.0	Light	3-8[b]
B[c]	ZRV Skimmer	6	229 mm dia. 15.2 m length	Ice-free water - calm	2.5-3.5	Light	3-8
C1[d]	ZRV Skimmer	6	152 mm dia. ≃ 23 m length	Ice-free water - calm	1.0-3.0	Heavy	3
C2[d]	ZRV Skimmer	6	254 mm dia. ≃ 23 m length	Ice-free water - calm	2.0-5.0	Light	3
D1[e]	Remote skimmer	2	254 mm dia. ≃ 4 m length	Ice-free water - calm	0.5-1.0	Heavy	6
D2[e]	Remote Skimmer	2	254 mm dia. ≃ 4 m length	Ice-free water - calm	0.5-1.0	Medium	9

(a) Source: This report.
(b) Slick thickness between ice.
(c) Source: Breslin (1978).
(d) Source: Urban et al (1978).
(e) Source: Lichte et al (1981).